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AD847558

AD
RDTE PROJECT NO.
USAAVSCOM PROJECT NO. 68-42
USAAVNTA PROJECT NO. 68-42

PERFORMANCE EVALUATION OF THE OH-6A WITH EXPANDED TOLERANCE MAIN ROTOR BLADES

Letter Report

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JANUARY 1969

ARMY AVIATION SYSTEMS TEST ACTIVITY
Edwards Air Force Base California 93523

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LETTER REPORT

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DEPARTMENT OF THE ARMY
U. S. ARMY AVIATION TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

SAVTE-C(E)

SUBJECT: Performance Evaluation of the OH-6A with Expanded Tolerance Main Rotor Blades

Commanding General
US Army Aviation Systems Command
ATTN: AMSAV-R-F

1. REFERENCES:

See inclosure 1.

2. BACKGROUND: In an effort to increase their main rotor blade production rate, Hughes Tool Company (HTC) submitted three Engineering Change Proposals (ref 1) in which they proposed expanding the acceptable production tolerance limits on outboard twist, inboard twist, and contour of the blades. The US Army Aviation Systems Command (USAAVSCOM) directed the US Army Aviation Systems Test Activity (USAAVNTA) to determine what effects on performance and tracking time would result from the expanded blade tolerances (ref 2). The HTC provided USAAVNTA with a set of four blades within the expanded tolerances on contour, a set of four blades within the expanded tolerances on inboard twist, and a set of four blades within the expanded tolerances on outboard twist.

3. TEST OBJECTIVES: The objectives of the test program (ref 2) were as follows:

a. Determine the true airspeed for the onset of blade stall for the three sets of expanded tolerance blades, a set of master blades, and a set of blades consisting of one blade of each type (ref 3).

b. Determine one level flight power required curve each for the three sets of expanded tolerance blades and a set of standard production blades.

c. Determine nondimensional in ground effect (IGE) hovering data for the standard production blades and the three sets of expanded tolerance blades.

d. Determine the time required for tracking the expanded tolerance blades.

4. DESCRIPTION:

a. The main rotor system of the OH-6A consists of four fully articulated blades with a radius of 13.17 feet. The blades are a 0015 air foil with a 6.75 inch chord. The blade has a 9-degree negative twist (ref 4).

b. Table 1 presents the deviations from the present tolerances for the individual blades as well as their individual order of installation for the test flights. The expanded tolerance blades are painted white on the top with a 6-inch yellow band at approximately station 40.

Table 1. Blade Description

Blade S/N	Area of Tolerance Deviation	Present Tolerance	Test Blade Value	Proposed Tolerance
58-4854	Outboard twist[1]	2.5° ± 0.5°	+ 0.77°	2.5° ± 0.75°
58-3268			+ 0.67°	
58-1587			- 0.77°	
58-1310			- 0.68°	
58-4388	Contour[2]	± 0.15 in.	+ 0.56 in	+ 0.160 in.
58-3806			- 0.205 in.	- 0.250 in.
58-4675			- 0.190 in.	
58-4022			- 0.256 in.	
58-4276	Inboard twist[3]	5.5° ± 0.5°	+ 0.92°	5.5° ± 1.0°
58-3823			+ 0.70°	
58-4512			- 1.20°	
58-1502			- 1.06°	
97-1900	USAAVNTA production blades[4]	-	-	-
97-2018				
97-2107				
97-4675				
58-1310	Outboard twist	2.5° ± 0.5°	-0.68°	2.5° ± 0.75°
58-1502	Inboard twist	5.5° ± 0.5°	-1.06°	5.5° ± 1.0°
97-2107	Production blades	-	-	-
58-4675	Contour	± 0.15 in.	-0.190 in	+0.160 in -0.250 in.

(1) Outboard twist varies 2.5° from station 118.8 to station 153.3.

(2) The contour tolerances are based on the sum of the contour differences at 36 points (top and bottom at 6 chordwise stations and 3 spanwise stations).

(3) Inboard twist varies 5.5° from station 24.3 to station 118.8.

(4) Not measured since delivery to USAAVNTA in October 1967.

5. SCOPE OF TEST:

a. Test flights were conducted to determine the effects of the expanded tolerance blades on blade stall airspeeds, hovering performance, and level flight performance. Blade tracking time was obtained for each set of expanded tolerance blades.

b. Four tests to qualitatively determine the airspeeds for the onset of blade stall were conducted at HTC using OH-6A serial number 65-12951. A flight was conducted with each set of expanded tolerance blades and a flight was conducted with a master set of blades. These four flights were conducted in a total flight time of 2.4 hours. A flight to qualitatively determine the airspeeds for the onset of blade stall was also conducted at USAAVNTA using OH-6A serial number 65-12927 with a blade configuration consisting of one production blade, one blade out of contour, one blade out of inboard twist and one blade out of outboard twist.

c. The hovering and level flight performance were obtained with the same three sets of expanded tolerance blades. The hovering and level flight performance data were obtained at USAAVNTA using OH-6A serial number 65-12927. Eight test flights were conducted at USAAVNTA for a total of 9.8 hours of flying time.

d. The time and number of flights required to track each set of blades were recorded as each set was installed at USAAVNTA.

6. METHODS OF TESTS:

a. The airspeeds at which the onset of blade stall occurred were obtained qualitatively. A USAAVNTA pilot and a HTC pilot flew each set of expanded tolerance blades as well as a set of master blades under the same conditions. The airspeed was slowly increased until a mutually agreeable limit airspeed and stall condition based on noise, vibration, and other pilot cues were reached. This airspeed is presented as the airspeed for the onset of blade stall. Blade stall characteristics were investigated at 100 percent N_2 (469 rotor rpm) and 103 percent N_2 (483 rotor rpm); at two density altitudes (2500 and 5000 feet); and at two power settings. Data were recorded manually and on an oscillograph. A USAAVNTA pilot flew the configuration consisting of one blade of each type. For this flight data were recorded manually and by a photopanel.

b. One level flight performance test was conducted with each set of expanded tolerance and the standard production blades. Each level flight was flown with the same takeoff gross weight and C.G. location and at the same thrust coefficient (C_T). The altitude was adjusted to maintain a constant weight to density (W/ρ) ratio as fuel was burned off, and the rotor speed was held constant throughout the flights. Data were recorded from cockpit instruments and on a photopanel.

c. Hovering performance data were obtained for each of the above sets of blades at a skid height of 4 feet (IGE). This hovering height was obtained by using a weighted chord attached to the skid and a ground crew member using hand signals to give the pilot his position relative to the proper height. When the pilot indicated the aircraft was stabilized, torque, rotor speed, fuel used, and atmospheric conditions were recorded. The aircraft gross weight was varied by adjusting ballast. Two rotor speeds were used at each weight. Data were recorded on a photopanel and from cockpit instruments.

d. The time required to track each set of expanded tolerance blades was recorded. The blade tracking procedures used are outlined in reference 5; however, upon receipt of reference 6, these procedures were varied slightly for the sets that were out of tolerance with respect to contour and inboard twist. The blade tabs on these two sets were not zeroed before installation in order to take advantage of whirl stand tracking at HTC (ref 6). Ground-run adjustments were made on pitch links only. The only blade tab adjustments made on these two sets were those outlined in reference 5 for airspeeds from 0 to 120 knots. The HTC personnel served in an advisory capacity for the final tracking of the set out of contour tolerances. The HTC revised tracking procedures (ref 7) were not followed, since tracking and flying were completed on all sets of blades prior to receiving the instructions in reference 8. For the configuration with one blade of each type the tracking procedures in reference 7 were followed for the three expanded tolerance blades, but the tab was zeroed and tracking procedures in reference 5 were followed for the standard production blade.

7. CHRONOLOGY:

a. Test Directive Received:	17 August 1968
b. Phase I tests performed at HTC:	22-23 August 1968
c. Expanded tolerance blades received:	26 August 1968
d. First test flight (production blades):	28 August 1968
e. Test flights completed on first directive:	27 September 1968
f. Preliminary report submitted:	4 October 1968
g. Final test flight completed:	31 October 1968
h. Final report submitted:	January 1969

8. RESULTS AND DISCUSSION:

a. General:

The aircraft performance was not adversely affected by installing any of the three sets of expanded tolerance blades. There were no significant differences in blade stall airspeeds between the master blades and the expanded tolerance blades. The hovering and level flight performance for the expanded tolerance blades compared closely to other OH-6A level flight and hovering performance. Tracking times for the expanded tolerance blades as pre-tracked by HTC were acceptable.

b. Blade Stall Airspeeds:

(1) The results of Phase I testing at HTC are presented in table 2. The results of the blade configuration flown at USAAVNTA are presented in Table 3.

Table 2. Blade Stall Airspeeds (OH-6A S/N 65-12951).

Blade Set	Density Altitude (ft)	Rotor Speed (rpm)	True Airspeed for blade stall onset (kt)[1]	True Airspeed for heavy blade stall (kt)[2]
Master blades	2400	469	115	125
Master blades	5190	469	108	114
Master blades	2395	483	127	132
Master blades	5310	483	115	128
Out of tolerance with respect to outboard twist.	2170	469	112	124
	4960	469	106	117
	2270	483	133	145 (500 fpm
	4960	483	118	127 descent)
Out of tolerance with respect to contour.	2475	469	110	123
	5090	469	102	112
	2560	483	126	131
	5230	483	118	124
Out of tolerance with respect to inboard twist.	2665	469	115	126
	4925	469	115	123
	2720	483	128	136
	4980	483	123	132

[1] Torque required for level flight was used in determining airspeeds for blade stall onset.

[2] An 80 psi torque was used for determining airspeed for heavy blade stall.

NOTE: Takeoff gross weight = 2715 lbs; C.G. Location = Sta. 100.1 (mid); Main rotor center hub fairing and blade root fairings removed.

NOTE: Both airspeeds were obtained in level flight except where noted.

Table 3. Blade Stall Airspeeds (OH-6A, S/N 65-12927).

Gross Weight (lb)	Density Altitude (ft)	Rotor Speed (rpm)	True Airspeed for Blade Stall onset (kt)(1)	True Airspeed for Heavy Blade Stall (kt)(2)
2704	2316	469	107	118
2671	4879	469	104	115
2704	2442	483	112	122
2681	4970	483	112	120
2407	2604	469	116	129
2373	4901	469	110	129
2415	2598	483	127	129
2384	4970	483	121	134
2131	2487	469	124	133
2101	4806	469	108	129
2142	2679	483	Blade stall airspeed not reached	
2115	5097	483	130	138

(1) Torque required for level flight was used in determining airspeeds for blade stall onset.

(2) An 80 psi torque was used for determining airspeed for heavy blade stall.

NOTE: One production blade - one blade out of inboard twist one blade out of contour - one blade out of outboard twist.

NOTE: C.G. location = Sta. 99.5 - 100.2 (mid). Main rotor center hub and blade root fairings removed.

NOTE: Both airspeeds were obtained in level flight.

(2) The airspeeds for blade stall for the blades out of outboard twist tolerances corresponded closely to those of the master set.

(3) The set of blades out of contour tolerances exhibited 1 - 5 kt lower airspeed for blade stall onset than did the master blades.

(4) The set of blades out of inboard twist tolerances had higher airspeeds for blade stall than the master blades in every case.

(5) The blade configuration consisting of one blade of each type showed lower airspeeds for blade stall onset at 2700 pounds than any of the four configurations tested at HTC.

c. Level Flight Performance:

(1) The level flight test results are presented in figure 1 of inclosure 2.

(2) The data points for the expanded tolerance blades fall within the "scatter" limits for the standard production blades shown. The blades out of tolerance with respect to outboard twist show slightly more power required at high airspeeds, but the overall level flight performance for the OH-6A was not significantly changed by using these expanded tolerance blades.

d. Nondimensional Hovering Performance:

(1) The hovering performance results are presented in figure 2 of inclosure 2.

(2) The IGE hovering performance for the three sets of expanded tolerance blades compares closely to that for various sets of standard production blades.

e. Blade Tracking Time:

(1) The tracking efforts for each set of blades are presented in table 4.

(2) The tabs of the first set of blades to be tracked were zeroed in accordance with the tracking procedures in reference 5, since reference 6 had not been received. This resulted in increased tracking efforts.

(3) The blades out of contour were the quickest of the four sets to track. Although HTC personnel were present, the tracking procedures were the same as those for the blades with expanded inboard twist tolerances.

(4) The tab was zeroed on the standard production blade when tracking the blade set consisting of one blade of each type. The tracking procedures outlined in reference 7 were followed for the three expanded tolerance blades.

(5) The HTC personnel suggested setting the individual pitch links during blade installation tc specific settings determined during whirl stand tracking. This procedure was found to increase tracking time and effort rather than reduce tracking time.

f. Validity of Test Results:

Sufficient results were not obtained from the limited flights conducted to fully evaluate the effects of expanded tolerance blades. Only a limited number of combinations were tested. No combination of blades were tested with more than one expanded tolerance condition on individual blades.

9. CONCLUSIONS:

a. In comparison to the master blades, the expanded tolerance blades generally exhibited a decrease in airspeed for onset of blade stall at a rotor speed of 469 rpm and an increase in airspeed for onset of blade stall at a rotor speed of 483 rpm (table 2).

b. The level flight power required for all three sets of expanded tolerance blades compared closely to that required for the Phase D and LOH competition standard production blades (fig 1 and para 8c).

c. The IGE hovering performance for all 3 sets of expanded tolerance blades compared closely to the hovering performance for the standard production blades used on the Phase D testing and the LOH competition (fig 2 and para 8d).

d. Blade tracking times are not excessive if the set has been pre-tracked on a whirl stand (para 8e and table 4).

Table 4. Expanded Tolerance Blade Tracking Efforts (OH-6A, S/N 65-12927).

Blade Set	Number of Flights	Flight Time	Number of Ground Runs	Ground Running Time	Packing Unpacking Installing and Removing Time	Adjustment Time After Ground Runs	Adjustment Time After Flights
Out of tolerance with respect to outboard twist[(1)]	10	3 hrs, 10 min	6	30 min	7 hrs	30 min	1 hr, 50 min
Out of tolerance with respect to contour	4	1 hr	3	15 min	5 hrs	1 hr, 15 min	1 hr, 5 min
Out of tolerance with respect to inboard twist	4	1 hr, 15 min	5	25 min	3 hrs	1 hr, 30 min	45 min
One blade of each type	7	1 hr, 55 min	10	1 hr, 40 min	5 hrs	40 min	1 hr, 30 min
Standard production blades	6	2 hr, 25 min	6	45 min	4 hrs	1 hr, 30 min	55 min

(1) Tracking procedures recommended by HTC were not followed, in that trim tabs were zeroed. Proper tab procedures were followed for the other sets.

e. Sufficient results were not obtained from the limited flights conducted to fully evaluate the effects of expanded tolerance blades (para 8f).

10. RECOMMENDATIONS:

a. The revised tracking procedures for expanded tolerance blades should accompany each expanded tolerance blade (para 8e(2)).

b. All expanded tolerance blades should be conspicuously identified so that maintenance attention will be focused on the requirement for a deviation from normal tracking procedures (para 4b).

John W. Elliott

JOHN W. ELLIOTT
Colonel, TC
Commanding

4 Incl
1. References
2. Test Data
3. Distribution
4. DD Form 1473

INCLOSURE 1. REFERENCES

1. Engineering Change Proposals 1685, 1642, and 1677, Hughes Tool Company, 2 August 1968.

2. Teletype message USAAVSCOM, AMSAV-R-EF, subject, "Test Directive, Limited Performance Evaluation of the OH-6A with Expanded Tolerance Main Rotor Blades," 17 August 1968.

3. Teletype message, USAAVSCOM, AMSAV-R-EF, subject, "ATA Project 68-42, OH-6A Blade Investigation," 10 October 1968.

4. "Detail Specification, OH-6A," HTC-AD 369-Y-8011, 8 December 1967.

5. TM 55-1520-214-20, Organizational Maintenance Manual, "Helicopter, Observation OH-6A Hughes," December 1967.

6. Teletype message, USAAVSCOM, AMSAV-R-EF, subject, "Pre-Track of OH-6A Rotor Blades," 11 September 1968.

7. Teletype message, HTC-AD, subject, "Blade Tracking Procedures," 24 September 1968.

8. Teletype message, USAAVSCOM, AMSAV-R-EF, subject, "USAAVNTA Project 68-42, OH-6A Blade Investigation," 27 September 1968.

9. The USAAVNTA Test Report, "Engineering Flight Test of the OH-6A Helicopter, Phase D," US Army Aviation Systems Test Activity, Project 65-37, July 1968.

10. The USAAVNTA Test Report, "Engineering Flight Test of the OH-6A," LOH Competition, 1967, US Army Aviation Systems Test Activity Project, 67-13, December 1967.

INCLOSURE 2. TEST DATA

FIGURE 1

LEVEL FLIGHT PERFORMANCE

OH-6A S/N 65-12927

2405 LBS MID C.G.

5000 FT H_D 486 RPM

$C_T = 0.0048$

SYMBOL	BLADES OUT OF TOLERANCE WITH RESPECT TO:
□	OUTBOARD TWIST
◇	CONTOUR
△	INBOARD TWIST

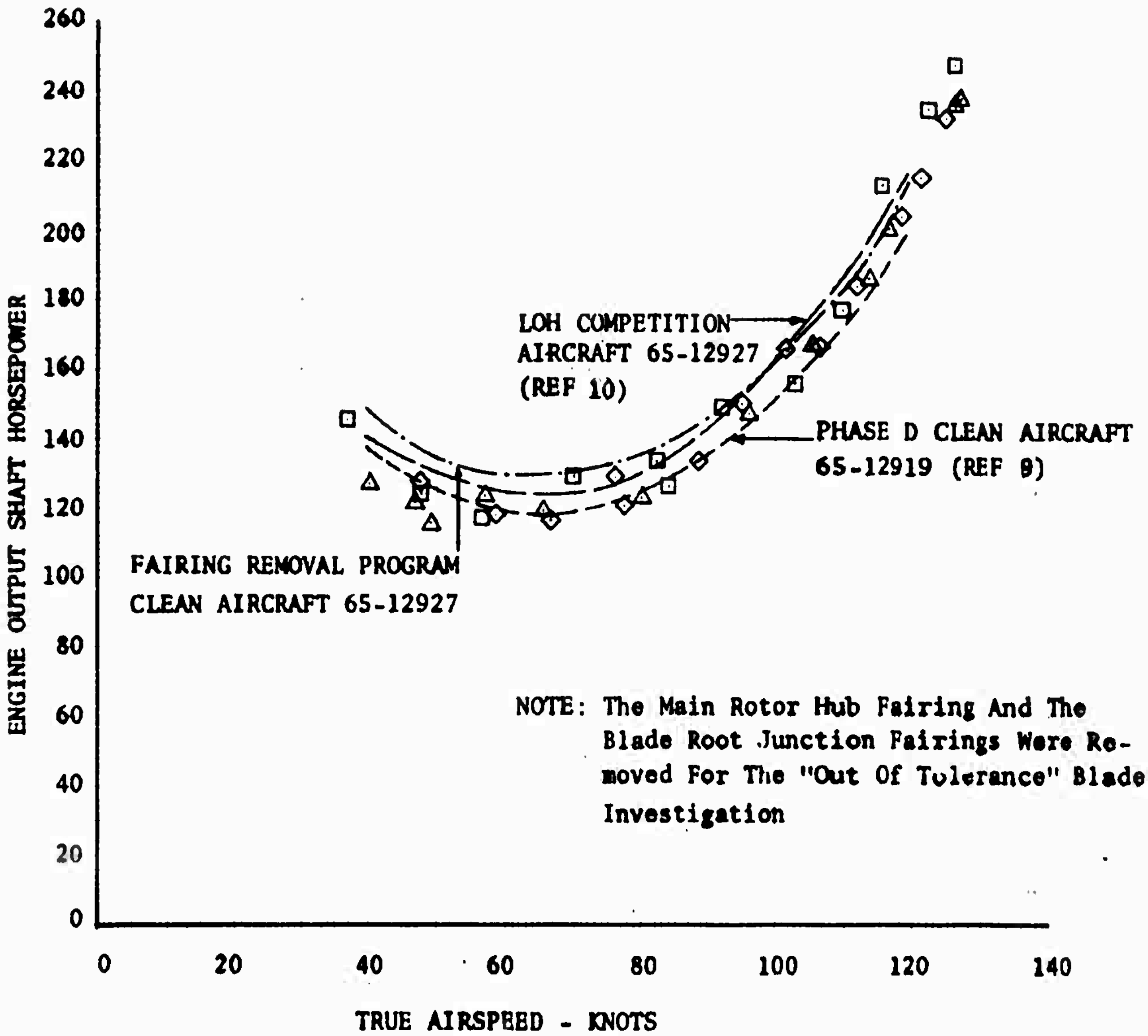


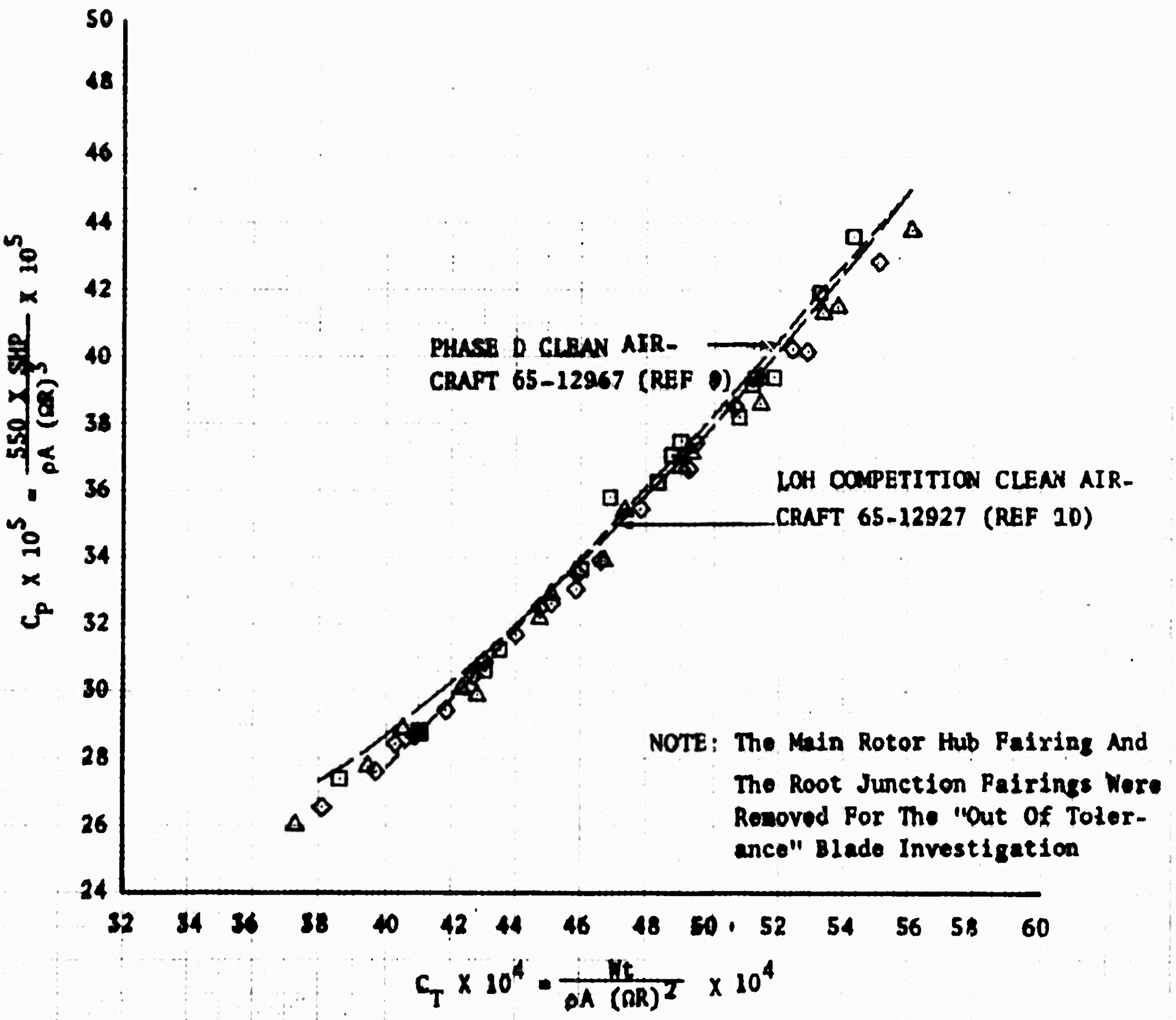
FIGURE 2

NON-DIMENSIONAL HOVERING PERFORMANCE

OH-6A S/N 65-12927

SKID HEIGHT = 4 FT (IGE)

SYMBOL	BLADES OUT OF TOLERANCE WITH RESPECT TO:
□	OUTBOARD TWIST
◇	CONTOUR
△	INBOARD TWIST



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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) US Army Aviation Systems Test Activity (USAAVNTA) Edwards Air Force Base, California 93523	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE
PERFORMANCE EVALUATION OF THE OH-6A WITH EXPANDED TOLERANCE MAIN ROTOR BLADES.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Letter Report, August 1968 through November 1968

5. AUTHOR(S) (First name, middle initial, last name)
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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
November 1968	17	10

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) USAAVNTA Project No. 68-42
b. PROJECT NO USAAVSCOM Project No. 68-42	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	N/A

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Commanding General US Army Aviation Systems Command ATTN: AMSAV-R-F PO Box 209, St. Louis, Missouri 63166

13. ABSTRACT
A limited performance evaluation was conducted to determine the effects of increasing the tolerances on contour, inboard twist and outboard twist on the OH-6A helicopter main rotor blades. The performance areas investigated were hovering performance, level flight performance and blade stall onset airspeeds. The tracking effort required for each set of blades was also investigated. Four blades with expanded contour tolerances, four blades with expanded inboard twist tolerances and four blades with expanded outboard twist tolerances were flown during this program. An additional blade configuration consisting of three blades with a different tolerance deviation on each blade and a standard production blade were flown to determine the blade stall onset airspeeds. The airspeeds for the expanded tolerance blades compared closely to the same blade stall airspeeds for a set of master blades. The hovering and level flight performance for the expanded tolerance blades compared closely to the hovering and level flight performance for standard production blades used on the Phase D test program and the LOH Competition. The tracking effort was acceptable for the expanded tolerance blades that had been pre-tracked on a whirl tower.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
OH 6A helicopter						
Limited performance evaluation						
Expanded tolerance main rotor blade						
Increasing tolerances						
Contour tolerances						
Inboard twist tolerances						
Outboard twist tolerances						
Hovering performance						
Level flight performance						
Blade stall onset airspeeds						
Tracking effort						